Mesa Verde Bircher Fire Hydrological Impact

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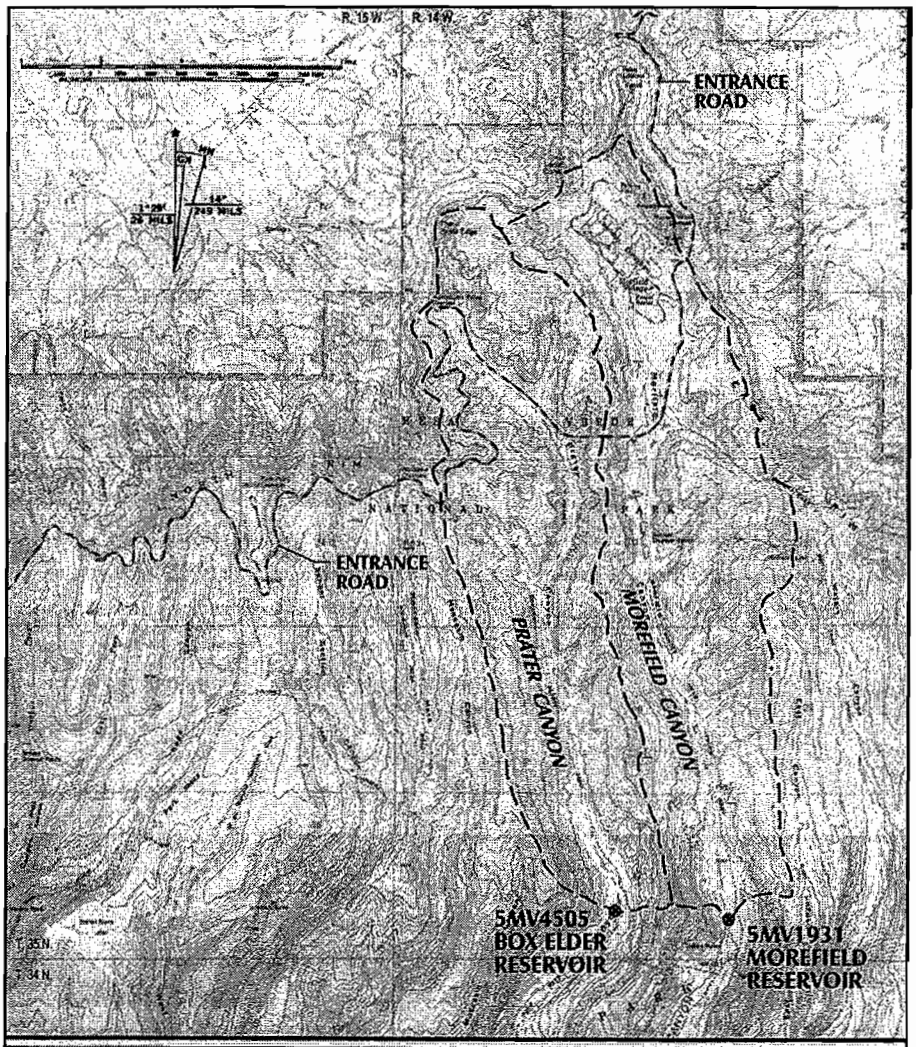
Introduction

The hydrological impact of a severe burn forest fire, when viewed from the vantage point of on-the-ground research hydrologists, is remarkable. While basin-wide impacts are measured in terms of increased curve numbers, increased flooding potential, vegetation and wildlife damage, and generalized potential soil loss via erosion, one can better understand post-fire changes when one also sees and measures detailed hydrological changes on a micro scale. It is then that the truly disastrous nature of a major forest fire hits home.

The 2000 Bircher Fire in the heart of the Mesa Verde National Park (MVNP) provided the opportunity for the Wright Paleohydrological Institute (WPI) to document detailed forest hydrology, riparian zone, and channel regime changes and to watch them happen. The opportunity was available because of our ongoing hydrological research in Mesa Verde for the five years preceding the fire, coupled with four years of study after the fire while performing paleohydrology studies under National Park Service (NPS) permits. The story that we saw unfold is not a pretty one in terms of both natural resource damage and loss of cultural archaeological artifacts.

Study Area

The study area is represented by Morefield Canyon and Prater Canyon, each having drainage basins of roughly 10.4 square kilometers (km^2) (4.0 square miles [mi^2]) upstream of our two archaeological study sites (Figure 1). The sites are Morefield Reservoir (5MV1931) and Box Elder Reservoir (5MV4505), which were designated as a National Historic Civil Engineering Landmark by the American Society of Civil Engineers (ASCE) in 2004. The reservoirs are from the AD 750 – 1100 period.



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PRATER AND MOREFIELD CANYON VICINITY MAP AND DRAINAGE BASINS TRIBUTARY TO SITES 5MV4505 AND 5MV1931

FIGURE **1**

WPI estimated the year 2000 pre-burn curve numbers (CN) of the two watersheds to be 60 or less, with vigorous forest growth of piñon and juniper trees interspersed with oak woodlands, Douglas fir, sagebrush, and meadow grass. Our analysis of the Morefield Canyon channel conditions before the fire told us that it had been decades since significant water had flowed overland (Figure 2). The forest was healthy and mature in both basins. The pre-fire basin conditions, because of fire suppression activities in the 100-year-old national park, could be judged to be more vegetated than under "natural" conditions.

The two canyons represented the highest population density of prehistoric Mesa Verde people of 1,200 years ago. At that time, the basins were much less forested than in the spring of 2000. The sites are roughly 19 kilometers (12 miles) southeast of Cortez, Colorado.

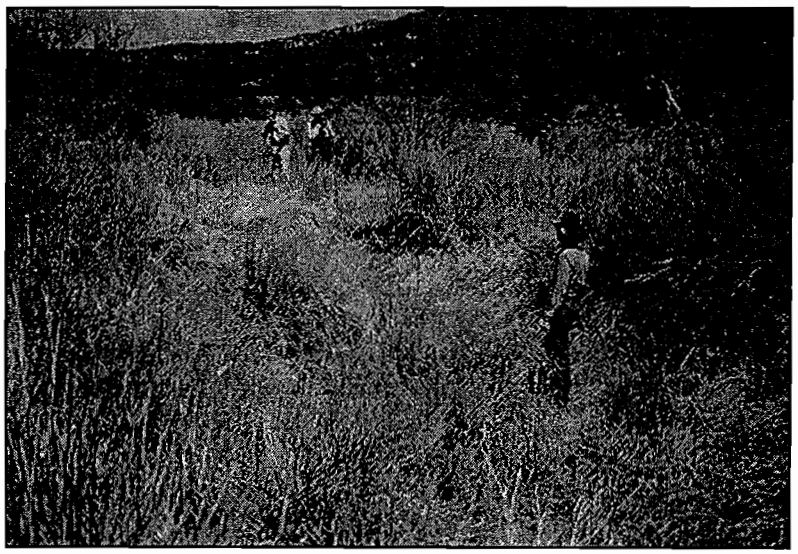


Figure 2. The thalweg of Morefield Canyon was heavily vegetated prior to the forest fire, providing evidence of infrequent flows. Rainfall and snowmelt mostly infiltrated into the ground until July 2000 when the disastrous fire occurred. Here, Doug Ramsey of the U.S. Department of Agriculture surveys the channel.

Bircher Fire

Lightening caused this fire in the eastern part of MVNP on July 20, 2000. The fire was controlled some 16 days later on August 5, 2000, after burning 9,360 hectares (ha) (23,220 acres). The centroid of the fire area was in the Morefield Canyon drainage basin and near the Prater Canyon watershed. According to the Burned Area Emergency Response (BAER) (U.S. Department of Interior 2000), much of the burned area in both Morefield and Prater Canyons was high burn severity. The canyon bottoms experienced low burn severity where there was meadow grassland and sagebrush.

The BAER report estimated that potential post-fire storm runoff discharges for the once-in-25-year frequency in Morefield Canyon would increase by seven fold, from 25 cubic meters per second (cms) (900 cubic feet per second [cfs]) to about 178 cms (6,300 cfs). BAER did not estimate the hydrological impact for more frequent runoff events, such as the 2-year frequency or those expected several times each year; however, for the 2-year frequency runoff, the increase in runoff would be from zero to perhaps a discharge approaching 3 cms (100 cfs).

It is the more-frequent runoff frequency that defines the canyon channels and tends to shape the riparian corridor. Confirming our estimates, BAER opined that the Morefield Canyon basin had been fire free for 100 years or more. This fire-free period estimate, based upon aerial photograph review, also applies to Prater Canyon. It should be noted that the BAER estimate of the pre-burn, 25-year frequency flood in Morefield Canyon is too high when compared with our 1997 field analyses of paleoflood hydrology reported to MVNP in December 1997. However, WPI was in overall agreement with the BAER assessment of August 10, 2000 and found that its evaluation was performed with a high standard of care and scientific expertise.

As a part of the pre-fire Morefield Canyon evaluations under the NPS permit, team member Dr. Robert Jarrett of the U.S. Geological Survey (USGS) undertook paleoflood studies in the canyon. His findings related to the last several hundred years of the Morefield flood history were consistent with the geomorphology analyses of the remainder of the research team. Paleoflood estimates were made at 12 sites along Morefield Canyon by Dr. Jarrett in 1997 from the Morefield campground to Site 5MV1931. Maximum paleoflood discharges range from about 7 to 10 cms (250 to 350 cfs) near Site 5MV1931. The paleoflood stage indicators are at least 100 years old and likely reflect the largest flooding in several hundred years. The minimal record of flooding in upper Morefield Canyon is likely due to a combination of: (1) thick, valley bottom pervious soils; (2) a mature forest; and (3) infrequent, localized rainstorms at higher elevations. Most of Morefield Canyon basin (upstream from 5MV1931) is above an elevation that is subject to extreme rainfall-produced flooding in southwestern Colorado.

Prehistoric Morefield Canyon

Prehistoric Morefield Canyon basin conditions, as determined by detailed field analyses in 1995-2000, are judged as follows for the AD 750-1100 period. It

was important to our research study to estimate ancient hydrological responses to determine prehistoric reservoir operational practices.

Ancient forest fires producing ash, on an average, occurred about once every 25 years according to an analysis of ash layers in the sediment layering in our archaeological trench of 1997 (Figure 3).

High runoff periods, usually represented by multiple events, occurred about once every 17 years, on the average, based on the layering contained in the Morefield Reservoir excavation of 1997.

Typical basin CN values, based on documented prehistoric agricultural land use (palynology studies), ancient forest cutting for firewood and clearing, and noted forest-fire evidence, were estimated to be about 75 for the 10.9 km^2 (approximately 4.2 mi^2) basin. This compares to a 1995 to 1999 (pre-fire) typical basin CN of 60 or less, with some prehistoric smaller area conditions approaching a CN of 87 from time to time due to recovering localized basin areas following burning and prehistoric agricultural activities.

Morefield Canyon

WWE made post-fire observations in Morefield Canyon on August 20, 2000; October 19, 2000; May 18, 2001; October 10, 2002; and May 1-4, 2003.

In August 2000, large portions of the burned area from the 2000 Bircher Fire were judged to be hydrophobic. An observed rainfall of about 6.3 millimeters (0.25 inch) in 15 minutes caused significant flow from canyon wall gullies; even small ones carried runoff. Many of these minor discharges caused small, shallow sediment flows onto the canyon floor at the discharge points of the gullies. By October 19, 2000, the thalweg of Morefield Canyon and Site 5MV1931, where the drainage area is about 10.9 km^2 (4.2 mi^2), was significantly changed from prior conditions. Sediment and ash deposits had been deposited from several previous modest runoff events that were in the range of 0.4 to 0.8 cms (14 to 28 cfs). Sediment gradation analyses collected from the canyon thalweg by Ernest Pemberton and Kenneth Wright are presented in Table 1. The collection effort is shown in Figure 3.

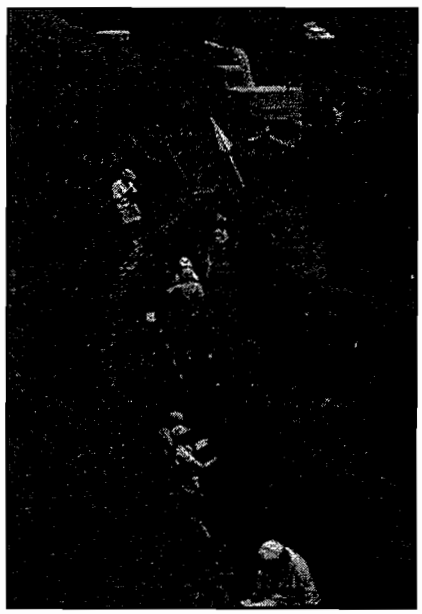


Figure 3. The excavation of the Morefield Reservoir in 1997 provided data on prehistoric flooding and forest fires.

TABLE 1
POST-FIRE BED MATERIAL SIZE GRADATION
MOREFIELD CANYON—MAY 18, 2001

Size (mm)	Percent Finer Than Size in Column 1		
	Sample #10	Sample #11	Average
1.19	100	100	100
.590	99	99	99.0
.297	95	92	93.5
.149	70	60	65.0
.074	32	29	30.5
.050	17	17	17.0
.005	10	9	9.5
.002	7	7	7.0

The 2000 Bircher Fire had created a markedly changed riparian condition in the valley bottom of Morefield Canyon (Figure 4).

Figure 4. View looking upstream from Morefield Reservoir after 2000 Bircher Fire showing new sand deposits on the canyon floor (10/10/2000).

One year after the fire, by May 18, 2001, the burn areas in Morefield Canyon showed only minor improvement in rainfall-runoff characteristics from the previous fall. Then, observations of Morefield Canyon at Site 5MV1931 in October 2002 showed continued modest runoff events from the burned areas, as represented by new sand deposits along the Morefield Canyon thalweg (Figure 5). Three years after the fire, in May 2003, the thalweg area was well covered with grass.

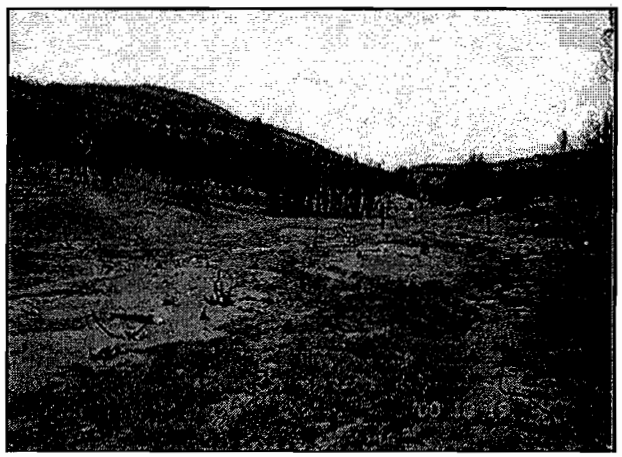


Figure 5. Looking upstream in Morefield Canyon from north end of Morefield Reservoir shown in the foreground (10/10/2002). Two years after the fire, the thalweg of Morefield Canyon showed increasing sand deposits and little vegetation.

The immediate post-fire rainfall-runoff conditions in August 2000 in Morefield Canyon can be compared with the documented pre-fire (1995 to 1999) conditions as follows:

1. The frequency of runoff had increased for small rainfall amounts. (Before 2000, the thalweg of Morefield Canyon was judged to have been flow free for a decade or more.)
2. Side tributary alluvial fans had more active and defined runoff flow paths.
3. Large quantities of sediment were being transported from burned canyon walls to the main channel as a result of the burn.
4. Head cuts had increased below sediment-deposition areas.
5. Sediment wash was being deposited on trails and vehicle tracks.
6. Sediment deposits in the main channel contained charcoal high-water marks.
7. The low-flow channel was clearly defined by deposited sediments and scour as compared to pre-fire conditions.
8. More wind and waterborne deposits of sediment were found in the vegetative areas.
9. Grass had expanded into many areas once covered with sagebrush.
10. Overland flow increased, with more rills for rapid water conveyance.
11. Although meadows appeared lush after two years, there was no evidence of brush regrowth.
12. Depositional and erosional sequences occurred on sides of the valley.
13. Scrub oak was re-sprouting in most of the oak thickets.

14. In areas of dense piñon and juniper trees, the intense heat of the fire caused considerable spalling and cracking of boulders. Large boulders (0.6 to 1.2 m [2 to 4 feet] in diameter) are surrounded by a circle of spalled fragments. These lens-shaped, spalled fragments had sharp edges and were commonly 15 to 20 centimeters (6 to 8 inches) across and 2.5 to 5 centimeters (1 to 2 inches) thick. This activity was critical to archaeology because it also cracked and spalled relic building stones.

By October 2002, the burned area of Morefield Canyon exhibited the following changes during the 27-month period since the fire:

1. A reduction in the estimated burn area rainfall-runoff CN was observed from 87 to 80 for high severity burn areas. Prior to the 2000 fire, the CN was estimated to be 60 or less.
2. There was a significant reduction of ash wash off into the riparian corridor.
3. On some canyon walls, there was an initial recovery of canyon wall greening with clusters of scrub oak, having a density of about 10 green plants per 93 square meters (m^2) (1,000 square feet [ft^2]).
4. Although canyon bottom grass showed recovery of about 75 percent, there was a complete absence of heavy growth of sagebrush, which existed prior to the fire.
5. Due in part to 2002 being a drought year, wetland areas that formerly contained cattails, ponded water, and miscellaneous vegetation were essentially dry and thus represented a decreased groundwater table.
6. Frequent thalweg discharges of 0.4 to 0.8 cms (15 to 30 cfs) and related sediment deposits were observed, whereas previously the thalweg would seldom carry water (i.e., a 2-year runoff of 0 cms [0 cfs]).
7. Active, minor head cutting of the thalweg channel was occurring.

Prater Canyon

Prater Canyon is similar to Morefield Canyon. Prater Canyon (5MV4505) was studied in the field in October 2002 and May 2003. Prior to the 2000 Bircher Fire, there was a valley floor with a good cover of sagebrush, grass, and small plant growth; the land use was characterized as ungrazed rangeland. The sides of the canyon are steep, with upland areas of piñons and junipers interspersed with rock outcroppings and clusters of scrub oak. In October 2002, the low-intensity valley bottom burn area in the vicinity of Site 5MV4505 was subject to data collection and monitoring that consisted of:

- Mapping of topography.
- Surveying of channel cross sections.
- Infiltration testing.
- Drilling auger holes.

- Surveying and evaluating the canyon channel thalweg.

The information thus collected indicated that for this drainage area of about 10.4 km^2 (4.0 mi^2), the following conditions existed:

1. High measured infiltration rates of 20 to 32 centimeters (8 to 13 inches) per hour on the canyon floor where the burn severity was low and there was no hydrophobicity, as would be expected for these soils. Runoff would be negligible except during exceptionally intense rainstorms.
2. At an elevation of about 60 meters (200 feet) above the canyon floor, a measured infiltration rate of 23 centimeters (9 inches) per hour near Site 5MV3190 was documented in an area of high intensity burn. At this location, there was no hydrophobicity and the measured infiltration rate was high even though the soil surface showed only minor vegetation recovery. Runoff caused surface erosion was noted, likely because of the steeper slope and lack of vegetation and duff.
3. Vegetation recovery along the slope of the canyon wall was limited to clusters of scrub oak, having a density of 20 to 40 plants per 93 m2 (1,000 ft2), along with general modest grass and small plant growth that did not represent more than a total of about 50 percent of normal cover. There was no sagebrush recovery on the valley bottom, where previously sagebrush was abundant.
4. During 2002, there was little or no evidence of ash wash inflow to the canyon thalweg channel.
5. Recent (2002) thin deposits of sediment from side tributaries were frequently present on the canyon floor, some reaching all the way to the thalweg channel.
6. An active head cutting phenomena in the canyon thalweg was observed near Site 5MV4505, where the streambed is unstable and is characterized by localized armoring with stones having a D50 of about 5 centimeters (2 inches).
7. We noted that surface erosion is damaging documented archaeological sites on the west side of the canyon where archaeological sites were inspected.

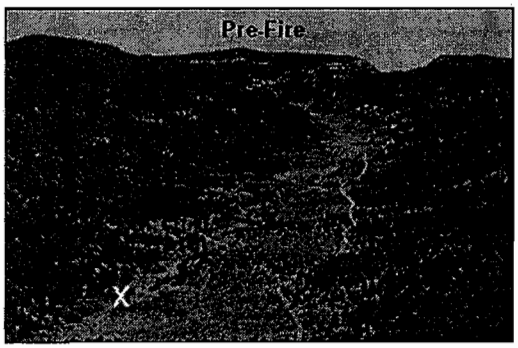
Based on information available from aerial photograph analysis and visual observations in the headwaters of the Prater Canyon drainage basin, the pre-burn CN for the basin was about 60 or less. Immediately after the fire, the CN was likely about 87. Although grass in the canyon floor meadows in October 2002 indicated about 80 percent recovery, sagebrush had not begun to recover even in areas known to have had a heavy cover of sagebrush prior to the fire. Local box elder trees were just beginning to recover, with a few new leafy branches apparent. The piñon and juniper forest was decimated. As of May 2003, it was estimated that the high severity burned areas likely recovered to a CN of 80, similar to that of Morefield Canyon.

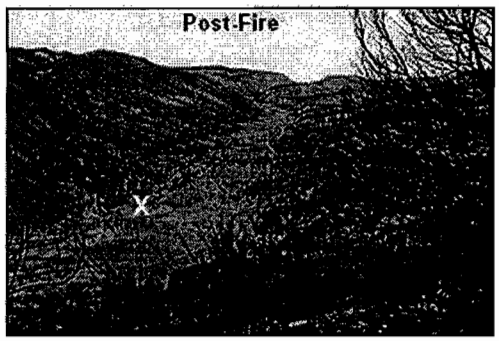
Summary

The juniper-piñon forested canyon slopes of Morefield and Prater Canyons were still considered to be subject to very high runoff potential in May 2003, some 33 months after the Bircher Fire. A precipitation event of 50 millimeters (2 cubic meters) of rainfall in an hour would likely create a runoff volume of as much as 29,000 km^2 (60 acre-feet per mi^2), with large sediment flows, channel erosion, and significant damage to archaeological sites.

The Prater and Morefield Canyon basins show a limited recovery between August 2000 and May 2003 (Figures 6 and 7), represented by a CN improvement from 87 to 80. The forest itself will likely require some 100 years to fully recover, though nearly all "natural" condition watershed response characteristics recovery will likely have occurred by 2020, with significant recovery by 2010.

On the other hand, the damage to archaeological sites can never be rectified. Damage is irreversible. Pieces of pottery and bones washed downhill, middens are eroded, building stones are spalled, and erosional channels are cut through archaeological sites. The heroic efforts of NPS personnel after the fire have mitigated damage, but only partially. Even now, additional funding could support important protective work by the NPS.





Figures 6 and 7. Pre- and post-Bircher Fire views of Morefield Canyon with the archaeological Site 5MV1931 reservoir mound shown to the left (marked with an "X"). Hydrological CNs for the watershed range from 60 or less for the pre-fire photograph to 87 for the burned conditions.

Acknowledgements

This paleohydrological field research and documentation effort in Morefield Canyon and Prater Canyon from 1995 to 2002 owes much to the benevolence of the MVNP staff and continuing generous research grants from the Colorado Historical Society. The research was performed under permits issued by MVNP Superintendent Larry Weise, with the assistance of MVNP archaeologists Linda Towle, Larry Nordby, Cynthia Williams, and under the administrative control of Chief Ranger Charlie Peterson, all of whom provided substantial cooperation.

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